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Performance Comparison between Massive MIMO Based Network and Conventional LTE Network for High Speed Broadband Connection in Rural Areas of Tanzania

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Abstract

People in rural areas need high-speed broadband connection for various services, including e-governance, virtual class rooms, telemedicine, video-on-demand, and home entertainment. However, in order to provide broadband services, service providers must incur high deployment costs and should wait for a long time for return on investments. Long-Term Evolution (LTE) has been proposed to overcome high deployment cost, although this technology suffers from poor coverage in rural areas. Thus, massive Multiple-Input Multiple-Output (MIMO) with its favorable propagation phenomenon can be exploited as an alternative solution to boost signal coverage in rural areas. The current study compared the performance of broadband networks for Tanzanian rural areas based on massive MIMO technology and LTE. Performance comparison is confined to Reference Signal Received Power (RSRP), User Signal-Interference Noise Ratio (SINRu) and Downlink (DL) throughput metrics for 5 MHz, 10 MHz and 20 MHz channel bandwidths at 2.1 GHz and 700 MHz carrier frequencies. The results show that, in terms of RSRP and SINRu, the performance of massive MIMO network at 5 MHz is higher than that of conventional LTE networks at 10 MHz and 20 MHz. Massive MIMO network performs better at lower channel bandwidth, making it more suitable for deployment in rural areas.

1. Introduction

Most rural areas in Tanzania lack broadband services due to higher deployment costs of such services. Life in rural areas needs broadband connection for different services: e-governance, virtual class rooms, telemedicine, video-on-demand, and home entertainment, among others [1]. However, provision of broadband services require service providers to incur higher deployment costs and should wait for a long time for return on investments [2, 3]. One of the technologies that can help to reduce cost is Long Term Evolution (LTE), which was proposed by Rekawt et al. [4, 5]. LTE radio networks differ with several other radio access technologies; LTE uses a new type of multiple access based orthogonal frequency-division multiplexing (OFDM) technology and massive multiple-input multiple-output (MIMO) antenna technology [6].

Considering eight villages with 14.6 km^2, LTE requires a bandwidth of 5 MHz at 900MHz and 6 cells to serve 7582 users on average. Study by Larsson et al. [7] found that it is possible to reduce the reported bandwidth and number of cells if massive MIMO is considered as an alternative. This is because massive MIMO can use hundreds or thousands of antennas to serve more users in the same bandwidth [8]. In addition, massive MIMO has a potential to boost the coverage through a favorable propagation phenomenon [9]. Favorable propagation inherent in massive MIMO were exploited by Tchao et al. [10] to reduce the number of cells proposed by Yogapratama et al. [5] by deploying large cells. It is evident that a massive MIMO based network can bring down the cost via bandwidth and cell reduction. However, LTE networks can be used to provide broadband services in remote areas and need to be compared to massive MIMO based networks [10].

Several works on planning and performance evaluation of broadband networks can be found in literature. Yogapratama et al. [5] planned and analyzed the performance of 900 MHz and 1800 MHz LTE network for 5 MHz and 20 MHz channel bandwidths for rural Indonesia. Results show that using 900 MHz band at 20 MHz bandwidth would serve a better throughput and a smaller number of cells for selected areas.

Another study conducted by Tchao et al. [11] evaluated performance of 4G LTE networks, deployed in Ghana, at 2600 MHz frequency band. Throughput and coverage were computed to compare its performance based on different antenna configurations. The results of the research indicated that better performance in terms of throughput and coverage can be achieved by using several numbers of antennas at the base station.

Moreover, a similar study conducted by Cueto et al. [12] compared capacity and coverage of LTE-Advanced networks at 700 MHz and 2600 MHz bands. The study considered higher channel bandwidths (20 MHz, 40 MHz, 60 MHz 80 MHz and 100 MHz). The results showed a 700 MHz band to have better coverage and capacity. However, careful planning is required to properly benefit from this carrier frequency. To the best of our knowledge, a study that compares the performance between a massive MIMO based network and LTE network for high speed rural broadband connection in Tanzania is lacking in literature.

This paper presents a performance comparison between massive MIMO technology at 2.1 GHz carrier frequency and LTE network for provision of high speed broadband for Tanzanian remote areas. This was to support the initiative of the United Republic of Tanzania of ensuring an increased coverage of broadband services in rural areas from 60% in 2021 to 90% in 2024 [13].

The rest of this paper is organized as follows: section 2 covers on radio propagation models; section 3 provides methodology; section 4 covers results and discussion; and section 5 gives the conclusion.

2. Radio Propagation Models

Radio Frequency (RF) planning requires propagation models in order to predict coverage and link budget, among other performance parameters. These models are functions of frequency band, type of deployment area and type of application [14]. The type of deployment includes urban, suburban, and rural areas. Moreover, the models are classified as indoor and outdoor propagation models. Okumura-Hata, Longley-Rice, COST231-Hata and Durkin models are most applicable for outdoor environments. Okumura-Hata and COST231-Hata models find their wide range of applications in wireless communications systems.

The Okumura-Hata model [15] is applicable for cellular propagation to estimate channel behavior in the 150 MHz to 1500 MHz range. The coverage distance is from 1 km to 20 km. The Okumura model is defined as

$$L(dB) = FSL - A_{mu}(f, d) - G(h_{te}) - G(h_{re}) - G_{area} \tag{1}$$

Where the variables carry the following meaning:

$$FSL(dB) = 32.45 - \log(d) + 20\log(f) - 10\log(G_t) - 10\log(G_r); \tag{2}$$

FSL, Free Space Loss;
D, distance between the transmitter and receiver in km;
F, carrier frequency in MHz;
G_t, transmitter gain;
G_r, receiver gain;
$A_{mu}(f, d)$, median attenuation relative to free space;
$G(h_{te})$, base station antenna height gain factor;
$G(h_{re})$, mobile antenna height gain factor; and
G_{area}, Gain due to the type of environment.

On the other hand, COST231-Hata model provides path loss estimates for large urban cells of 1 km to 20 km, within a wide range of frequency, BS height of 30 to 200 m, and in rural, suburban or dense urban environments [15]. Equation (3) is a prediction formula used to determine path loss in rural environment.

$$Lp(rural) = Lp(urban) + 18.33\log(f_c) - 4.78\log(f_c)2 - 40.94 - a(Hue) \tag{3}$$

where

$$Lp(urban) = 33.9\log(f_c) + [44.9 - 6.55\log(Hbs)]\log(d) - 13.82\log(Hbs) - a(Hue)dB \tag{4}$$

$$a(Hue) = [1.1\log(f_c) - 0.7]Hue - [1.56\log(f_c) - 0.8] \tag{5}$$

Where the variables are defined as follows:

f_c ,system's carrier frequency (MHz);

Lp, path loss (dB);

Hbs, BS's antenna height (m);

Hue, user equipment's height (m);

D, separation distance between user equipment and the BS (km); and

a(Hue), user equipment antenna height correction factor.

The model presented by equation (3) was adopted for this study since COST231-Hata model provides better path loss for both rural and urban environment than Okumura-Hata model at higher carrier frequencies [16, 17].

3. Method

Existing methodologies for network planning were adopted in this study whereby link budgets were computed for both Uplink (UL) and Downlink (DL) directions. The coverage planning was accomplished with the help of a special planning tool, Infovista Planet. The tool was chosen among other tools because it is capable of modeling and planning most wireless technologies, including massive MIMO technology for 4th Generation (4G) and 5th Generation (5G) networks [18]. This tool is an open, scalable, and flexible multi-technology network design and optimization platform that supports network lifecycle, from initial design to densification and optimization. Link budget calculation is intended to obtain the Maximum Allowable Path Loss (MAPL) from User Equipment (UE) and Base Station (BS). The computed MAPL was subjected to the COST-231-Hata model in order to predict possible cell radius for a given site. The cell radius estimate was used as an input to Infovista Planet planning tool for automatic site creation and placement for the selected area of interest. In this study, an area of 43.5125 km^2 was selected and used as a representative sample for the rural areas of Tanzania selected from Dodoma region, Bahi district.

3.1 Experiments

3.1.1 Coverage Parameter Planning

Coverage planning involves DL and UL radio link budget designs. Its aim is to predict cell coverage on the basis of device capabilities. The MAPL was computed at this stage. Moreover, the maximum path loss for DL and UL was converted to cell radius with the help of a propagation model for rural deployment environments. Parameters, such as antenna height, antenna gains, path loss, transmitted power, and receiver sensitivity were included in the link budget calculation [19]. The massive MIMO technology was implemented on the New Radio (NR) system. The aforementioned parameters were subjected to equations (6), (7), and (8) in order to design link budgets for coverage planning.

$$Prx=Ptx+Gtx+Grx-Ltx+PM-PL \tag{6}$$

$$L_{MX}=Ptx+Gtx-Ltx-Rsens+Grx-Lrx+Gdiv \tag{7}$$

$$Rsens=kTB+NF+SINR+IM-Gdiv \tag{8}$$

Where the variables carry the following meanings:

Prx, received power (dBm);

Ptx, transmitter output power (dBm);

Gtx, transmitter antenna gain (dBi);

Ltx, cable loss and other losses in the Transmitter (dB);

Lrx, losses in the receiver side (dB);

EIRP, estimated effective Isotropic Radiated Power (dBm);

Rsens, receiver sensitivity (dBm);

NF, noise Figure (dB);

IM, interference margin (dB);

Gdiv, Diversity gain (dB);

SINR, Signal-to-Interference plus Noise Ratio (dB);

K, Boltzmann's constant;

B, Channel bandwidth (Hz);

T, Thermal noise temperature (K);

PM, Power Margin; and

PL, Free Space Path Loss.

Table 1 and Table 2 summarize the link budget calculations for UL and DL respectively.

Table 1. Link Budget Calculation for DL

Parameter	Unit	DL Calculation
	Transmitter-BS	
Tx RF Power	dBm	43
Tx Diversity Gain	dB	4
Tx RF line loss (cable loss)	dBi	1
Tx Antenna Gain	dBi	18
EIRP	dBm	6
	Receiver-UE	
Thermal Noise Power	dBm/Hz	-178.77
Noise Fig.	dB	7
SNR	dB	5
Fast Fade Margin	dB	4.5

Rx Diversity	dB	4
Rx Faded Sensitivity	dBm	-101.50
Rx Antenna Gain	dB	0
Rx line loss	dB	0
Effective faded receiver sensitivity	dBm	-101.50
Body, Vehicle, Building loss	dB	5
Interference Margin	dB	3
Maximum Allowable Path Loss (MAPL)	dB	157.50

Table 2. Link Budget Calculation for UL

Parameter	Unit	UL Calculation
Transmitter-UE		
Transmitter Power	dBm	24
Tx RF line loss (cable loss)	dB	0
Transmitter Antenna Gain	dBi	0
EIRP	dB	24
Receiver-BTS		
Thermal Noise Power	dBm/Hz	-178.78
Noise Fig.	dB	3
SNR	dB	-8
Fast Fade Margin	dB	8
Rx Diversity Gain	dB	4
Rx Faded Sensitivity	dBm	-139.78
Rx Antenna Gain	dB	18
Rx line loss	dB	7
Effective faded receiver sensitivity	dBm	-128.78
Interference Margin	dB	1
Maximum Allowable Path Loss (MAPL)	dB	151.78

3.1.2 Simulation Method

Simulation scenarios were created based on the channel bandwidth, whereby for each scenario, network analysis was run. Simulation scenarios I, II and III use 5 MHz, 10 MHz and 20 MHz channel bandwidths, respectively, for both Massive MIMO based network and LTE network. These channel bandwidths of 5 MHz, 10 MHz and 20 MHz were chosen for scenario creation because similar bandwidths are used in conventional LTE networks [20], and are mostly used in cellular networks. Results from network analysis were exported to Microsoft Excel 2016 software, ready for further data analysis using MATLAB software. Parameters for massive MIMO network and LTE network planning and simulation are summarized in Table 3 and Table 4 respectively.

Table 3. Parameters for massive MIMO Network Planning and Simulation

Parameter	Value	Unit
Carrier Frequency	2100	MHz
Propagation Model	COST-231- Hata	
MIMO Configuration	8x8	
Number of BS Antennas	192	
Tx Power-BTS	43	dBm
Tx Power-UE	24	DBm
Antenna Gain-BTS	18	Db
Tx Power-UE	24	DBm
Duplexing Mode	TDD	
Channel Bandwidth	5, 10, 20	MHz
BS Antenna Height	50	M
UE Antenna Height	1.5	M
Cell Radius	2.20	M
Coverage Area	43.5125	km^2

Table 4. Parameters for Conventional LTE Network Planning and Simulation

Parameter	Value	Unit
Carrier Frequency	700	MHz
Propagation Model	COST-231-Hata	
MIMO Configuration	2x2	
Tx Power-BTS	43	DBm
Tx Power-UE	24	DBm

Parameter	Value	Unit
Antenna Gain-BTS	18	dB
Tx Power-UE	24	dBm
Duplexing Mode	FDD	
Channel Bandwidth	5, 10, 20	MHz
BS Antenna Height	50	m
UE Antenna Height	1.5	m
Cell Radius	2.20	m
Coverage Area	43.5125	km^2

4. Results and Discussions

The study under this paper aimed at comparing the performance between massive MIMO based networks and conventional LTE networks based on three performance metrics, RSRP, SINRu and DL cell throughput. Moreover, the comparison was done at 5 MHz, 10 MHz and 20 MHz channel bandwidths. Simulation was done to study variation of RSRP, SINRu and DL cell throughput over given coverage area for all two types of networks under study. The results are detailed from Figures 1 to 9 and Tables 5 to 7.

In Figure 1, the RSRP in massive MIMO based networks is observed to be stronger than that of conventional LTE based networks at 5MHz channel bandwidth. This is because the use of massive MIMO antenna technology enhances good propagation of signals to far distances due to formation of beam forming. Furthermore, on average, a large area is covered by strong signals when massive MIMO technology is used. For example, RSRP ranging from -90 dBm to -85 dBm an area of 5.833125 km^2, 4.01 km^2 and 3.153125 km^2 is covered by massive MIMO based network when operated at 5 MHz, 10 MHz and 20 MHz channel bandwidths, respectively. On the other hand, an area of 2.2925 km^2, 0.46375 km^2 and 0.30375 km^2 is covered by conventional LTE network when operated at 5 MHz, 10 MHz and 20 MHz channel band-widths, respectively. Comparing the two network technologies, we find that massive MIMO based network works better in rural settings in terms of signal coverage for both channel bandwidths. However, the higher the channel bandwidth (10 MHz and 20 MHz) the less the geographical area is covered with strong signal level (RSRP) (Figures 2 and 3, and Table 5).

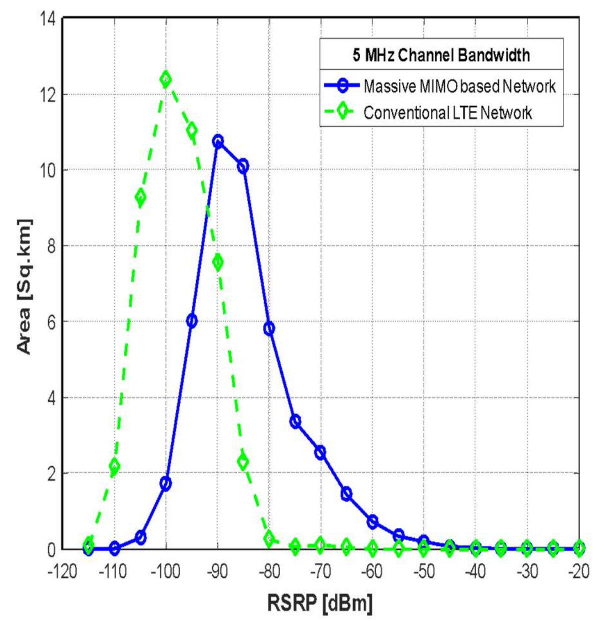

Figure 1. RSRP coverage comparison between Massive MIMO and Conventional LTE networks at 5 MHz channel bandwidth

In Figure 4, again the SINRu experienced in massive MIMO based networks at 5 MHz channel bandwidth is stronger than that experienced in LTE networks. SINRu of 5 dB to 90 dB covering an area of 0.043125 km^2 to 0.001875 km^2 respectively is observed when a massive MIMO based network is implemented in the selected rural area. Comparing the SINRu among channel bandwidths for all two technologies, it can be seen that the higher the channel bandwidth the weaker the SINRu (Figures 4, 5 and 6, and Table 6).

With 5 MHz channel bandwidth, SINRu for massive MIMO extends from 5 dB to 90 dB while for LTE, the SINRu extends from -10 dB to 30 dB.

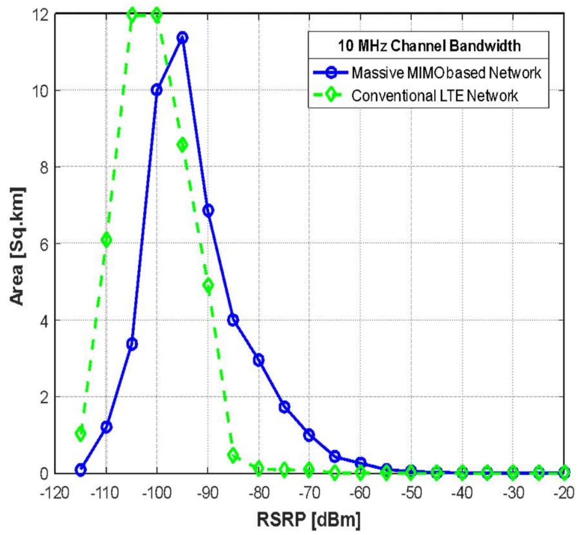

Figure 2. RSRP coverage comparison between Massive MIMO and Conventional LTE networks at 10 MHz channel bandwidth

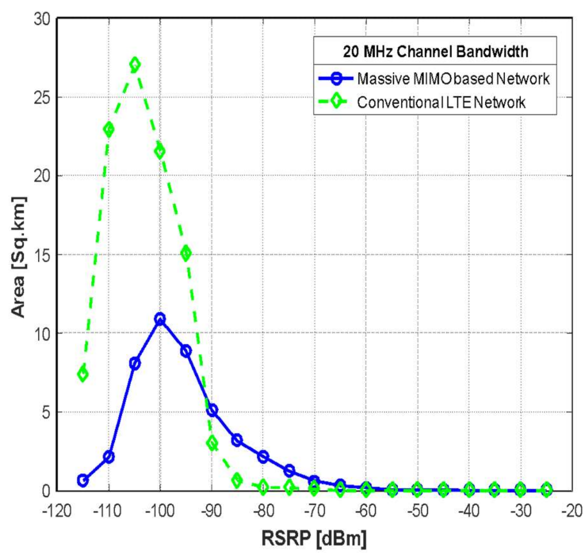

Figure 3. RSRP coverage comparison between Massive MIMO and Conventional LTE networks at 20 MHz channel bandwidth

For 10 MHz channel bandwidth with massive MIMO, the SINRu extends from 5 dB to 50 dB while for its counterpart, LTE technology, the SINRu extends from -15 dB to 30 dB to cover an area greater than 0 km^2. This observation signifies that, comparatively, better coverage is experienced with massive MIMO technology at 5 MHz at a cheaper price.

Table 5. RSRP coverage comparison between Massive MIMO and Conventional LTE Networks at 5 MHz, 10 MHz and 20 MHz Channel Bandwidths

RSRP(dBm)	Area covered (km^2) in Massive MIMO Networks			Area covered (km^2) in LTE Networks		
	Channel Bandwidths in MHz					
	5	10	20	5	10	20
-120 ~ -115	0.004375	0.091875	0.616875	0.085625	1.0225	3.406875
-115 ~ -110	0.30375	1.196875	2.1275	2.18875	6.116875	10.53375
-110 ~ -105	1.735625	3.381875	8.085625	9.27125	11.97437	12.38687
-105 ~ -100	6.018125	10.01	10.88375	12.40625	11.97687	9.890625
-100 ~ -95	10.76875	11.40125	8.913125	11.02937	8.57875	6.9325
-95 ~ -90	10.09125	6.87	5.139375	7.59	4.91625	1.4025
-90 ~ -85	5.833125	4.01	3.153125	2.29625	0.46375	0.30375
-85 ~ -80	3.365625	2.948125	2.174375	0.25875	0.1125	0.099375
-80 ~ -75	2.558125	1.740625	1.236875	0.0675	0.101875	0.08625
-75 ~ -70	1.429375	0.99625	0.59125	0.111875	0.075	0.044375
-70 ~ -65	0.729375	0.420625	0.31	0.051875	0.016875	0.001875
-65 ~ -60	0.341875	0.25625	0.151875	0.003125	0.005625	0.009375

-60 ~ -55	0.191875	0.1025	0.058125	0.006875	0.00625	0.0025
-55 ~ -50	0.073125	0.045625	0.030625	0.005625	0.0025	0.000625
-50 ~ -45	0.03625	0.021875	0.01625	0.000625	0	0
-45 ~ -40	0.01875	0.0125	0.0075	0	0	0
-40 ~ -35	0.010625	0.005	0.000625	0	0	0
-35 ~ -30	0.00125	0.000625	0.00125	0	0	0
-30 ~ -25	0.00125	0.000625	0	0	0	0

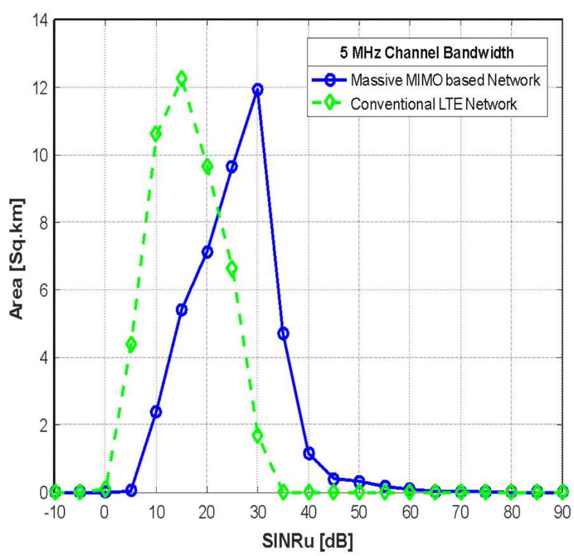

Figure 4. SINRu coverage comparison between Massive MIMO and Conventional LTE networks at 5 MHz channel bandwidth

For the case of DL throughput at 5 MHz channel bandwidths, we find that massive MIMO networks perform better than LTE networks. This can be seen from Figure 7. DL throughput extends from 4 Mbps to 32 Mbps in massive MIMO networks while with LTE networks DL throughput extends from 0 Mbps to 24 Mbps at 5 MHz. However, more throughput is experienced in large geographical areas from 20 Mbps to 32 Mbps for massive MIMO networks. This is because massive MIMO technology has better spectral efficiency.

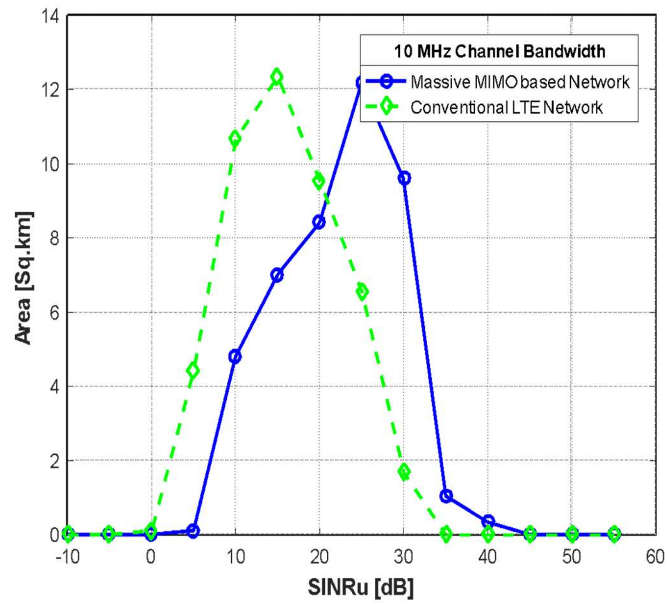

Figure 5. SINRu coverage comparison between Massive MIMO and Conventional LTE networks at 10 MHz channel bandwidth

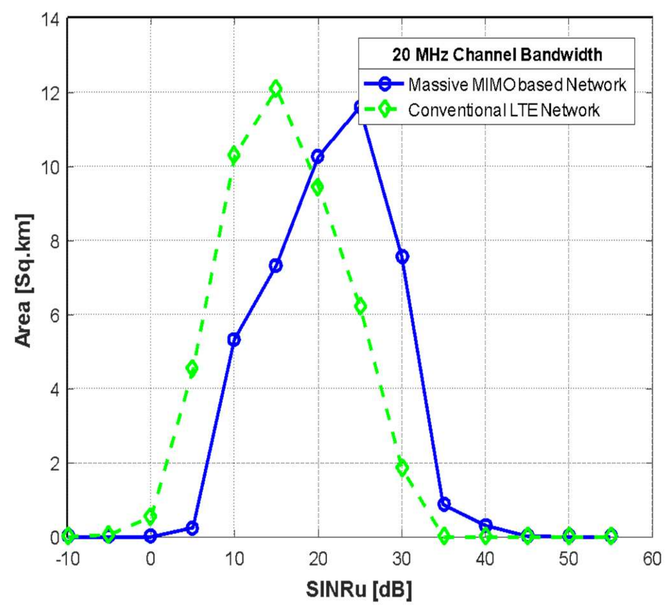

Figure 6. SINRu coverage comparison between Massive MIMO and Conventional LTE networks at 20 MHz channel bandwidth

Table 6. SINRu coverage comparison between Massive MIMO and Conventional LTE Networks at 5 MHz, 10 MHz and 20 MHz Channel Bandwidths

SINRu (dB)	Area covered (km^2) in Massive MIMO Networks			Area covered (km^2) in LTE Networks		
	Channel Bandwidths in MHz					
	5	10	20	5	10	20
-15 ~ -10	0	0	0	0.000625	0.000625	0.000625
-10 ~ -5	0	0	0	0.00375	0.00375	0.066875
-5 ~ 0	0	0	0	0.114375	0.116875	0.549375
0 ~ 5	0.043125	0.109375	0.233125	4.405625	4.4425	4.554375
5 ~ 10	2.371875	4.795	5.33125	10.61687	10.67187	10.31
10 ~ 15	5.42125	7.01125	7.31375	12.2575	12.355	12.09312
15 ~ 20	7.12875	8.4275	10.26437	9.655625	9.543125	9.466875
20 ~ 25	9.66875	12.17	11.59687	6.620625	6.55625	6.213125
25 ~ 30	11.945	9.595625	7.569375	1.69875	1.68	1.846875
30 ~ 35	4.71125	1.04875	0.8675	0	0	0
35 ~ 40	1.159375	0.345	0.315625	0	0	0
40 ~ 45	0.398125	0.009375	0.005625	0	0	0
45 ~ 50	0.323125	0.000625	0.000625	0	0	0
50 ~ 55	0.17875	0	0	0	0	0
55 ~ 60	0.08625	0	0	0	0	0
60 ~ 65	0.038125	0	0	0	0	0
65 ~ 70	0.025625	0	0	0	0	0
70 ~ 75	0.008125	0	0	0	0	0
75 ~ 80	0.001875	0	0	0	0	0
70 ~ 85	0.00125	0	0	0	0	0
85 ~ 90	0.001875	0	0	0	0	0

With this observation, it can be concluded that massive MIMO could suit rural areas application as compared to LTE network since smaller channel bandwidth provides better DL throughput to large areas. When the comparison is extended to higher channel bandwidths, still massive MIMO networks outperform the LTE network in terms of DL throughput (Figures 8 and 9, and Table 7). However, higher channel bandwidths provide better throughput than coverage which does not hinder the use of massive MIMO technology for rural areas at cheaper prices. Higher channel bandwidths are expensive, and thus are not suitable for rural area applications.

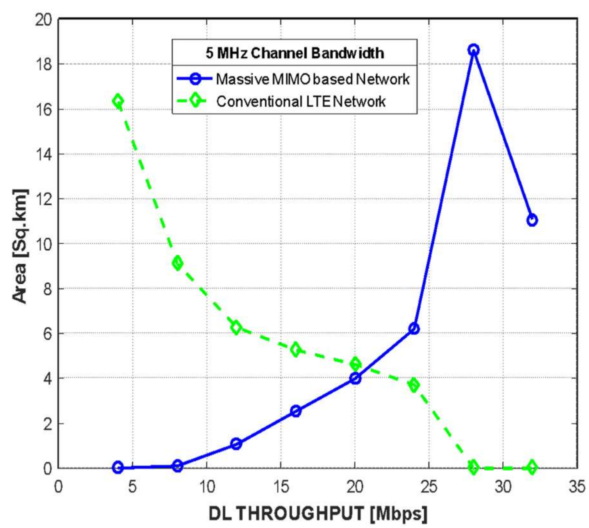

Figure 7. DL Throughput coverage comparison between Massive MIMO and Conventional LTE networks at 5 MHz channel bandwidth

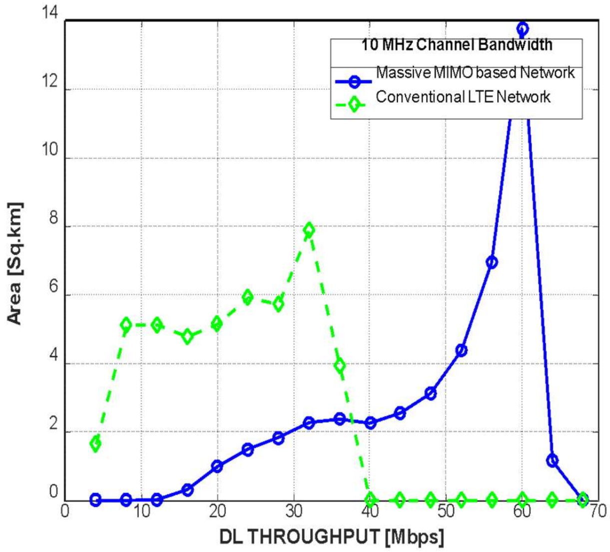

Figure 8. DL Throughput coverage comparison between Massive MIMO and Conventional LTE networks at 10 MHz channel bandwidth

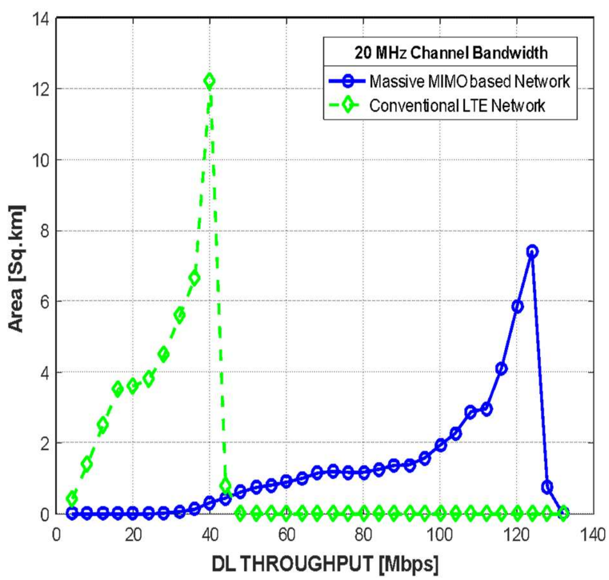

Figure 9. DL Throughput coverage comparison between Massive MIMO and Conventional LTE networks at 20 MHz channel bandwidth

Table 7: DL Throughput coverage comparison between Massive MIMO and Conventional LTE Networks at 5 MHz, 10 MHz and 20 MHz Channel Bandwidths

DL Throughput (Mbps)	Area covered (km^2) in Massive MIMO Networks			Area covered (km^2) in LTE Networks		
	Channel Bandwidths in MHz					
	5	10	20	5	10	20
0 ~ 4	0	0	0	16.34937	1.64375	0.4275
4 ~ 8	0.088125	0	0	9.118125	5.116875	1.42
8 ~ 12	1.056875	0.010625	0	6.283125	5.13875	2.50875
12 ~ 16	2.514375	0.30875	0	5.274375	4.7875	3.528125
16 ~ 20	3.97125	0.993125	0	4.629375	5.163125	3.6275
20 ~ 24	6.203125	1.503125	0.0025	3.719375	5.9225	3.80375
24 ~ 28	18.61437	1.833125	0.0175	0	5.736875	4.498125
28 ~ 32	11.06437	2.28125	0.05375	0	7.905	5.594375
32 ~ 36	0	2.379375	0.1225	0	3.955625	6.67125
36 ~ 40	0	2.255625	0.325625	0	0	12.21625
40 ~ 44	0	2.556875	0.441875	0	0	0.805625
44 ~ 48	0	3.1325	0.624375	0	0	0
48 ~ 52	0	4.38	0.738125	0	0	0
52 ~ 56	0	6.958125	0.810625	0	0	0
56 ~ 60	0	13.77125	0.9025	0	0	0

60 ~ 64	0	1.14875	1.009375	0	0	0
64 ~ 68	0	0	1.154375	0	0	0
68 ~ 72	0	0	1.19	0	0	0
72 ~ 76	0	0	1.173125	0	0	0
76 ~ 80	0	0	1.174375	0	0	0
80 ~ 84	0	0	1.25	0	0	0
84 ~ 88	0	0	1.35875	0	0	0
88 ~ 92	0	0	1.378125	0	0	0
92 ~ 96	0	0	1.573125	0	0	0
96 ~ 100	0	0	1.934375	0	0	0
100 ~ 104	0	0	2.283125	0	0	0
104 ~ 108	0	0	2.880625	0	0	0
108 ~ 112	0	0	2.9725	0	0	0
112 ~ 116	0	0	4.119375	0	0	0
116 ~ 120	0	0	5.860625	0	0	0
120 ~ 124	0	0	7.40875	0	0	0
124 ~ 128	0	0	0.738125	0	0	0
128 ~ 132	0	0	0	0	0	0

5. Conclusion

Performance evaluation between a massive MIMO based network and conventional LTE network for high-speed broadband connection in rural areas of Tanzania has been presented in this paper. Based on simulation results, it can be seen that LTE RSRP decays faster than that of the massive MIMO network at 5 MHz bandwidth. This means that LTE network offers less received signal strength for coverage areas when compared to massive MIMO. Moreover, the UE experiences better SINRu in massive MIMO than in conventional LTE network at both channel bandwidths. There is close similarity in coverage area but massive MIMO provides higher SINRu at almost the same coverage area. For example, an approximate area of 12 km^2 is covered with 30 dB SINRu when using massive MIMO while the same area is covered with 10 dB SINRu when using LTE network at 5 MHz. A 20 dB gain is obtained while using massive MIMO.

CONTRIBUTIONS OF CO-AUTHORS

Marko Mwalongo	[ORCID: 0000-0002-1885-8190]	Conceived the idea and wrote the paper
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